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Acoustical Performance of Noise Barriers

Highway 417, North and South Sides, West of Woodroffe Avenue, Ottawa

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ABSTRACT

This report evaluates the acoustical performance of the highway noise barriers erected on opposite sides of the Ottawa Queensway (Highway 417) between Woodroffe Avenue and Pinecrest Road. The north-side barrier, built in 1980, has a height of 3 m (10 ft.) above the edge of pavement elevation. The south-side barrier was built in 1981 and has a height of 4 m (13 ft.) above original ground.

The average sound level attenuations measured in the back yards adjacent to the barriers on the north and south sides were about 5 dBA and 10 dBA, respectively. A good agreement was obtained between the average measured and the average calculated attenuations.

Sound level attenuations could not be measured accurately at locations shielded by one or two rows of houses due to the large variable influence of community noise and other factors on the sound levels at these locations.

Sound level measurements indicated that the subsequent construction of the south-side barrier had no definite effect on the acoustical performance of the north-side barrier.

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1/ INTRODUCTION

This report is one of a series of reports which evaluate the acoustical performance of the highway noise barriers constructed by the Ministry of Transportation and Communications (MTC) in Ottawa, along Highway 417, [1,2]. The noise barriers evaluated herein are situated on opposite sides of the Ottawa Queensway (Highway 417) between Woodroffe Avenue and Pinecrest Road. In this region, Highway 417 has 4 lanes and the terrain is relatively flat.

The north-side barrier was built in 1980 and has a height of 3 m (10 ft.) above the edge of pavement elevation. Its length is approximately 410 m. The south-side barrier, erected in 1981, has a height of 4 m (13 ft.) above original ground and a length of about 390 m. Both barriers were constructed of vertical steel panels and run along right-of-way limits. Barrier alignments and heights are shown in Figure 1. Both barriers are "tucked-in", as shown, to minimize sound leakage around the barrier ends. Where the barriers are opposite each other, they are about 55 m apart.

2/ MEASUREMENT OF BARRIER ATTENUATIONS

Before and after construction sound level measurements were performed at nine observation points behind the north-side barrier, and at two points behind the south-side barrier. The observation points were located as shown in Figure 1. The method used to determine the measured barrier attenuation at each observation point is briefly outlined below.

The before construction sound level measurements on each side of the highway were performed independently, using two or more sound level monitors simultaneously. One monitor, the control monitor, was stationed, at a control measurement location C.M. (see Figure 1). The other monitor(s), the site monitor(s), were stationed at the observation points shown in Figure 1, 5 to 10 m away from the houses. All measurements were taken with the control and site monitors at 1.2 m above ground. Measurement periods were of 20 or 30 minute duration.

The after construction sound level measurements were conducted in the same manner, with the monitors placed at the identical locations and heights as those used in the before surveys.

The barrier attenuation, adjusted for variations in highway traffic, was determined at each observation point using the expression:
Barrier attenuation at location i = $(L_{AC} - L_{Ai}) - (L_{BC} - L_{Bi})$

where:

L_{AC} = after construction sound level measured at the control measurement location

L_{Ai} = after construction sound level measured at location i

L_{BC} = before construction sound level measured at the control measurement location

L_{Bi} = before construction sound level measured at location i

The measured sound levels and attenuations are presented in Table A1 of the Appendix. The instrumentation used and the results obtained in the before construction sound level survey conducted on the north side are discussed in Reference 3.

3/ EVALUATION OF MEASURED BARRIER ATTENUATIONS

Before and after construction sound level measurements were performed to determine the reductions in sound levels achieved by each barrier. The subsequent construction of the south-side barrier was used to evaluate its possible effect on the acoustical performance of the north-side barrier. The objective was to provide further insight into the effect the construction of a barrier has on the sound levels behind an existing barrier on the opposite side. The schedule of the construction of the barriers and of the sound level surveys is shown below.

SURVEY	SURVEY IDENTIFICATION[1]	LOCATION OF SURVEY	CONDITIONS WHEN TAKEN	SURVEY DATE
1	BB	North Side	Before either barrier was constructed	January 1979
NORTH-SIDE BARRIER WAS CONSTRUCTED				
2	A1	North Side	After north-side barrier was constructed	July 1980
3	B	South Side	After north-side barrier was constructed	November 1980
SOUTH-SIDE BARRIER WAS CONSTRUCTED				
4	A2	North Side	After both barriers were constructed	July 1981
5	A2	South Side	After both barriers were constructed	July 1981

NOTE: [1]The same survey identification is used in Table A1 of the Appendix.

As indicated above, a sound level survey (Survey 1) was conducted on the north side before either barrier was constructed. After the north-side barrier was constructed, sound level surveys were taken on both sides of the highway (Surveys 2 and 3). Repeat surveys (Surveys 4 and 5) were then taken on both sides of the highway after the south-side barrier was constructed. The barrier attenuations measured in these surveys are presented in Table A1, Column 7.

The attenuations measured on the north side after only the north-side barrier was constructed (Survey 2) were compared with the attenuations measured after both barriers were erected (Survey 4). The comparison was based on the Student's t-test for paired comparisons [4]. The test showed no statistically significant difference between the attenuations measured in both surveys. In other words, no definite degradation in north-side barrier performance due to the erection of the south-side barrier was observed. Possible causes for the differences between the attenuations measured in both surveys are discussed in Section 5.2.

Since no statistically significant difference between the attenuations measured in both north-side surveys was observed, the attenuations were combined. The combined attenuations on the north side, as well as the attenuations on the south side (after both barriers were constructed) are presented in Table A1, Column 8. These attenuations are compared with the corresponding calculated attenuations in Section 5.

4/ CALCULATION OF BARRIER ATTENUATIONS

Calculations for single barriers could be employed since no definite effect on barrier performance due to the opposing barrier was observed. The method of calculation is briefly outlined below.

The before and after construction L_{eq} sound levels were calculated using a highway traffic noise prediction model [5] modified by the MTC as described in Reference 6. The same model is used to prepare design advice for construction of noise barriers. Actual barrier alignments and heights were used in the calculations. The calculated sound levels were based on 1980 hourly traffic volumes derived by dividing the AADT by 18. These hourly traffic volumes were used in order to approximate the traffic volumes experienced during sound level measurements.

The difference between the before and after construction sound levels represents the calculated barrier attenuation (barrier insertion loss, ΔL_{eq}) at a given location.

5/ COMPARISON OF MEASURED AND CALCULATED ATTENUATIONS

The measured and calculated attenuations were compared to verify the accuracy of the prediction model used. The measured and calculated sound level attenuations are presented in Table 1. The table is divided into two parts: Table 1, Part A, lists the results for locations not shielded by houses, i.e., for locations in the back yards adjacent to the barriers. Table 1, Part B lists the results for locations shielded by one or two rows of houses. The following observations were made based on the findings presented in Table 1.

5.1/ Locations Not Shielded by Houses

The average measured sound level attenuation at locations not shielded by houses on the north side was about 5 dBA. This compares favourably with the average calculated attenuation of approximately 6 dBA. The average measured sound level attenuation at locations not shielded by houses on the south side was about 10 dBA. The prediction model used overestimates the measured attenuations at these locations by about 1.5 dBA.

The calculated attenuations, presented in Table 1, Column 4, have been adjusted for sound transmission through the steel barrier material. The method used to calculate the adjustments was developed by Jung [7]. Average reductions in attenuations of about 0.5 dBA and 1.0 dBA were required for locations adjacent to the north- and south-side barriers, respectively. Possible causes for the differences between the measured and calculated attenuations are treated in Section 5.2.

5.2/ Locations Shielded by One or Two Rows of Houses

The average measured attenuation at observation points on the north side, shielded by one or two rows of houses, was about -1 dBA. The average calculated attenuation at these locations was approximately 1.5 dBA. The

negative attenuation of 1 dBA indicates an increase in the average measured sound level after barrier construction. This negative attenuation does not necessarily mean an actual long-term increase but is probably due to barrier-unrelated differences between the measured before and after construction sound levels which could not be adjusted for by the control measurements. Causes of these differences include the following:

a/ Sound Absorption by Ground Cover

The before construction measurements were conducted during winter when the ground was covered with approximately 75 cm of snow. The after measurements were conducted during summer. Sound absorption by the snow covered ground may have reduced the before construction sound levels. This would result in a lower measured attenuation.

b/ Community Noise Sources and Environmental Factors

The sound levels behind a barrier are not solely governed by noise emitted by highway traffic, but are also influenced by highly variable community noise sources such as local traffic and children playing. The influence of community noise sources increases with distance behind the barrier and is large at locations shielded by one or two rows of houses. Environmental factors such as wind direction and temperature gradients also have an effect on the relatively low sound levels at these locations. The above variable influences on the sound levels could not be adjusted for by the control measurements and hence affect the measured attenuations.

A quantitative evaluation of the above effects is presented in Reference 8. In conclusion, it is probably unrealistic to expect to observe significant reductions in highway traffic noise at these locations, since the average before construction sound levels were already about 50 dBA (typical for residential areas not subjected to expressway noise).

6/ CONCLUSIONS

1/ The average barrier attenuations measured in the backyards adjacent to the barriers on the north and south sides were about 5 dBA and 10 dBA, respectively.

A good agreement was obtained between the average measured and the average calculated attenuations at these locations.

2/ An average sound level increase of about 1 dBA was measured at locations shielded by one or two rows of houses on the north side after the barrier was constructed. This increase does not necessarily mean an actual long-term increase in sound levels but is probably due to barrier-unrelated differences between the measured before and after construction sound levels which could not be adjusted for by the control measurements. Possible causes of these differences are discussed in Section 5.2.

The average calculated attenuation at these locations was approximately 1.5 dBA.

3/ No definite effect on the acoustical performance of the north-side barrier due to the subsequent construction of the south-side barrier was indicated from the limited number of sound level measurements performed.

4/ Improved accuracy in measuring barrier attenuation at locations influenced to a large degree by community noise may be achieved by repeated measurements performed under rigidly controlled conditions.

7/ REFERENCES

[1] Hajek, J.J., "Noise Barrier Attenuation, Highway 417, North Side, East of Island Park Drive, Ottawa," Report AE-81-05, Research and Development Branch, Ministry of Transportation and Communications, Ontario, April 1981.

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[3] Giles, G.B., and Desormeaux, J., "Ambient Noise Level Measurements in the Vicinity of a Proposed Noise Barrier, Queensway North Side, West of Woodroffe Avenue, Ottawa," Report 79-AC-02, Experimental Demonstration & Testing Group, Ministry of Transportation and Communications, Ontario, February 1979.

[4] Bennett, C., and Franklin, N., Statistical Analysis in Chemistry and the Chemical Industry, John Wiley & Sons, Inc., New York, 1954, Chapter 5.

[5] Kugler, B.A., Commins, D.E., and Galloway, W.J., "Highway Noise, A Design Guide for Prediction and Control," National Cooperative Highway Research Program Report 174, Transportation Research Board, Washington, D.C., 1976.

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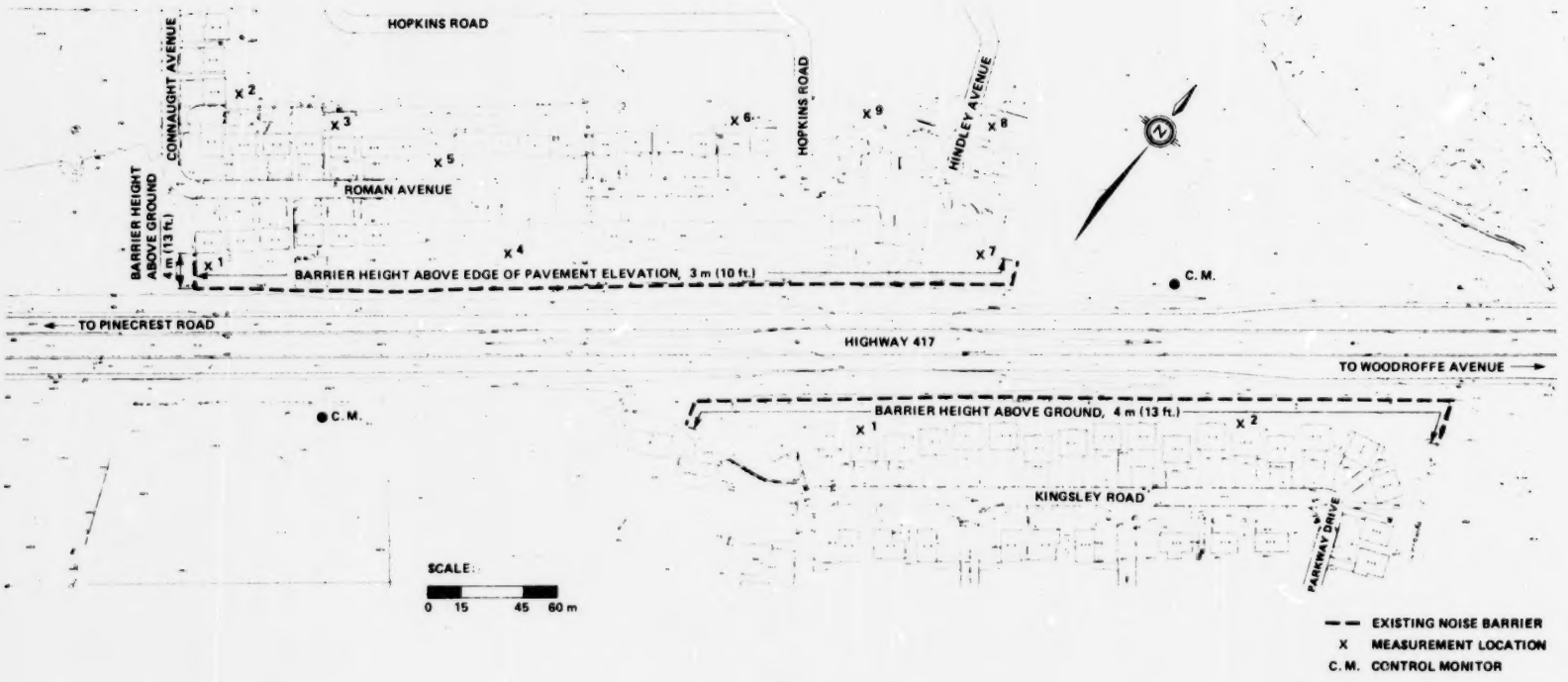

Figure 1/ General Barrier Setting with Measurement Locations

Table 1/ COMPARISON OF MEASURED AND CALCULATED BARRIER ATTENUATIONS

Measurement Location[1]	Measured Sound Levels After Barrier Construction[2] L_{eq}	Measured Attenuations[3] ΔL_{eq}	Calculated Barrier Attenuations Using: Single Barrier Calculation[4] ΔL_{eq}
1	2	3	4
Part A Locations Not Shielded by Houses			
North			
1	60.9	3.6	3.4
4	61.2	5.4	7.2
7	63.0	6.0	6.7
Average	61.7	5.0	5.8
South			
1	65.4	10.2	11.5
2	65.9	9.7	11.5
Average	65.7	10.0	11.5
Part B Locations Shielded by One or Two Rows of Houses			
North			
5	56.2	3.1	2.9
8	54.4	-2.4+	0.5
2	51.7	0.3	0.5
3	52.1	-1.6+	1.4
6	48.9	-0.7+	1.4
9	51.6	-4.6+	2.9
Average	52.5	-1.0+	1.6

NOTES:

[1] Measurement locations are shown in Figure 1.

[2] The sound levels are obtained by combining the (A) sound levels from Table A1, Column 5, and are unadjusted for traffic and other variations.

[3] The attenuations are taken from Table A1, Column 8 and are adjusted for traffic and other variations using control measurements.

[4] The attenuations are adjusted for reduction in attenuation due to sound transmission through the barrier.

+ Increase in sound level rather than attenuation

APPENDIX

Table A1/ MEASURED SOUND LEVELS, L_{eq}

Locat. No[1]	Date	Time	Control Measure-ment	Site Measure-ment[2]	Differ-ence (4-5)	Measured Attn.[3] ΔL_{eq}	Averaged Measured Attn.[4] ΔL_{eq}
1	2	3	4	5	6	7	8
North							
1BB[5]	79-01-10	15:50	80.0	62.0	18.0		
1A1	80-07-31	10:00	81.5	61.0	20.5	2.5	
1A1	80-07-31	15:08	82.0	61.0	21.0	3.0	
1A2	81-07-22	10:55	84.0	60.6	23.4	5.4	3.6
2BB	79-01-11	15:05	81.0	50.0	31.0		
2A1	80-07-31	15:45	82.0	50.0	32.0	1.0	
2A2	81-07-22	10:55	84.0	53.4	30.6	-0.4+	0.3
3BB	79-01-11	9:45	81.0	49.0	32.0		
3A1	80-07-31	12:00	81.0	51.0	30.0	-2.0+	
3A2	81-07-22	10:45	84.0	53.2	30.8	-1.2+	-1.6+
4BB	79-01-10	15:50	80.0	64.0	16.0		
4A1	80-07-31	10:00	81.5	61.5	20.0	4.0	
4A1	80-07-31	15:08	82.2	61.0	21.2	5.2	
4A2	81-07-22	11:40	84.0	61.1	22.9	6.9	5.4
5BB	79-01-11	10:25	81.0	58.0	23.0		
5A1	79-07-31	10:35	80.6	53.9	26.7	3.7	
5A2	81-07-22	11:45	84.0	58.5	25.5	2.5	3.1
6BB	79-01-10	15:00	81.0	47.0	34.0		
6A1	80-07-31	12:45	80.6	47.0	33.6	-0.4+	
6A2	81-07-22	11:40	84.0	50.9	33.1	-0.9+	-0.7+
7BB	79-01-10	10:30	81.0	68.0	13.0		
7A1	80-07-31	12:45	81.0	62.0	19.0	6.0	
7A1	80-07-31	15:45	82.0	63.0	19.0	6.0	
7A2	81-07-22	12:25	83.0	64.0	19.0	6.0	6.0
8BB	79-01-10	11:00	81.0	51.0	30.0		
8A1	80-07-31	11:15	81.0	53.0	28.0	-2.0+	
8A2	81-07-22	12:25	83.0	55.8	27.2	-2.8+	-2.4+
9BB	79-01-10	15:00	81.0	46.0	35.0		
9A1	80-07-31	10:35	81.0	54.0	27.0	-8.0+	
9A2	81-07-22	12:25	83.0	49.3	33.7	-1.3+	-4.6+
South							
1B	80-11-05	16:35	75.0	77.0	-2.0+		
1A2	81-07-22	15:40	73.5	65.4	8.1	10.1	
1A2	81-07-23	11:07	73.6	65.3	8.3	10.3	10.2
2B	80-11-05	17:00	75.0	77.0	-2.0+		
2A2	81-07-22	15:40	73.5	66.0	7.5	9.5	
2A2	81-07-23	11:07	73.6	65.7	7.9	9.9	9.7

Table A1/ MEASURED SOUND LEVELS, L_{eq}

NOTES:

1 Measurement locations are shown in Figure 1.

2 The sound levels are unadjusted for traffic and other variations.

3 The attenuations are adjusted for traffic and other variations using control measurements. The attenuations are obtained by subtracting the results given in Column 6 for the before series (B) from the results given in Column 6 for the after series (A).

4 The combined attenuations of Column 7.

5 Measurements taken:
BB - Before either barrier was constructed
A1 - After construction of north-side barrier
A2 - After construction of north and south-side barriers
B - After construction of north-side barrier but before construction of south-side barrier.
\+ - Increase in sound level rather than attenuation.